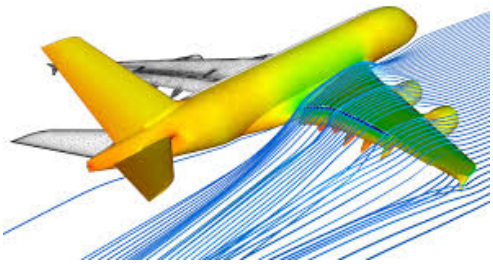
1.4 Fluid Dynamics

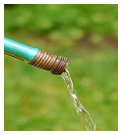


1. Physics Democracy!

Consider a tube with water flowing through it. How will velocity change if the area is reduced?

Stays Same	Increases (Flows Faster)	Decreases (Flows Slower)

Demo!



Flow rate increases as cross sectional area diminishes.

Fluid Motion

Fluid motion is difficult to analyze: try explaining the motion of a particle of water moving in a stream. The overall motion of the stream may be apparent, but any one particle may be next to impossible to observe and describdue to eddy currents, passage over obstructions, drag on the stream bottom, etc.

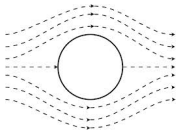
Luckily, in this section we ignore complications thrown at us by reality, and simplify fluid motion using some simple approximations.

Ideal Fluids - Condition 1

There are four characteristics of an ideal fluid that simplify our study:

1. Fluids have steady flow: all particles have the same velocity as they pass a given point.

A steady flow's path can be shown with streamlines, which never cross.



Streamlines require low velocities, or eddy currents will appear, and the flow becomes turbulent.

Finally, they indicate the relative magnitude of the velocity. Where they are close, velocity is greatest.

Ideal Fluids - Conditions 2 & 3

2. Fluids have Irrotational Flow - so no whirlpools or eddies.

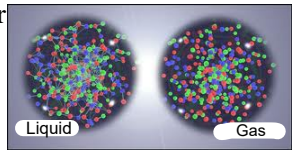
3. Flow is nonviscous - the molecules don't stick together, or to the sides of the tube.

Ideal Fluids - Condition 4

4. Fluids demonstrate incompressible flow, meaning that their density is constant as they move.

Liquids can be considered incompressible (although all matter is compressible if enough pressure is applied), but **gases** are highly compressible.

Liquid molecules are in contact with each other, but gas molecules are far apart, so gases have a lot more room to be pushed together



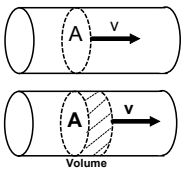
Volume Flow Rate

A volume of fluid passing an area per unit time is the volume flow rate. Units: m^3/s (volume/time).

BUT, calculations involve the area (A) of a pipe that fluid passes through, at some velocity (v).

Consider a cross sectional area (m^2) of water passing by a point at some velocity (m/s):

After time goes by, a volume (m^3) has passed the point:

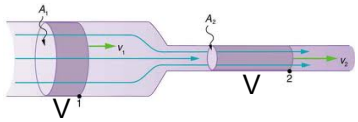


Relation: $A \bullet v = Volume\ Flow\ Rate$

Unit analysis: $A \bullet v = m^2 \bullet \frac{m}{s} = \frac{m^3}{s}$

Continuity Equation

If there are no fluid losses within a tube, the volume of fluid entering the tube equals the volume exiting (assuming constant ρ).



Different areas and velocities yields the SAME VOLUME!

Mathematically:

$A_1 v_1 = A_2 v_2$	A = Area (m^2) v = velocity (m/s)
AP Equation	

Flow Rate Examples

2. A pipe of area of 2.5 E - 4 m^2 flows at 3.1 m/s. If a demonstration requires a flow rate of 8.6 m/s, what will the area of pipe have to be?

$$A_1 v_1 = A_2 v_2$$

$$\frac{A_1 v_1}{v_2} = A_2 = \frac{2.5E-4m^2 \bullet 3.1m/s}{8.6m/s} = 9.0E-5m^2$$

3. If the pipe were circular, what radius would this be?

$$A = \pi r^2$$

$$r = \sqrt{\frac{A}{\pi}} = \sqrt{\frac{9.0E-5m^2}{\pi}} = 0.0054m$$

4. Aorta Blood Speed Problem

Blood flows at a rate of 5.00 L/min through an aorta with a radius of 0.01 m. What is the speed of blood flow in the aorta (in m/s)?

Hint: there are 1000 liters in a m^3.

4. Aorta Blood Speed Answer

Given:
Volume Flow Rate = 5.00 L/min
Radius = 0.01 m

Convert volume flow rate to m^3/s:

$$\frac{5.00L}{min} \bullet \frac{1min}{60s} \bullet \frac{1m^3}{1000L} = 8.33E-5m^3/s$$

Then, find aortal area (sounds funny!):

$$A = \pi r^2 = \pi(0.01m)^2 = 3.14E-4m^2$$

Finally: $A \bullet v = Volume\ Flow\ Rate$

$$v = \frac{Flow\ Rate}{A} = \frac{8.33E-5m^3/s}{3.14E-4m^2} = 0.265m/s$$

Homework 1.4

Preview 1.5

Problems 1.4 in your Booklet
Due: Next Class